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LEBANON BOLOGNA PROCESSING

by

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Lebanon bologna is a smoked, spiced, uncooked all-beef sausage with a characteristic fermented flavor, reddish mahogany color, fine firm texture upon cutting, and typically a large diameter (3½-4 in.). This sausage is made by a three step process consisting of aging, fermentation/smoking, and mellowing. It is chiefly manufactured in the Lebanon-Lancaster area of Pennsylvania.

Studies at the Eastern Regional Research Center on Lebanon bologna have been concentrated on the following specific areas: 1) use of starter cultures and nitrite to reduce dependency on natural flora for lactic acid production and for nitrate reduction; 2) use of lower levels of nitrate/nitrite to effect curing; 3) potential for nitrosamine formation; 4) influence of salt and spices on the fermentation; and 5) destruction of salmonellae.

Traditional Method of Manufacturing Lebanon Bologna. Coarse ground beef containing about 3% salt is aged at approximately 5°C for 10-14 days. At the end of the aging period, spices, sugars, and nitrate are added, and the meat mixture is finely ground and stuffed into fibrous casings. The sausages are smoked for 5-6 days in a wooden smokehouse with limited temperature and humidity control until the fermentation is complete. They are then mellowed at approximately 5°C for a few days, during which the harshness of freshly smoked bolognas is reduced and other desirable flavor changes occur. The commercial product has a pH of about 4.7, approximately 1% lactic acid, 12-15% fat, about 20% protein, and 56% moisture. The refrigerated shelf life is several months.

Starter Culture Method. The introduction of a commercial lyophilized culture of *Pediococcus acidilactici* enabled sausage producers to obtain consistent and reliable fermentations. The procedure for producing Lebanon bologna with the commercial culture is similar to that of the traditional process except that the sausages are placed in an air conditioned smokehouse at 27-32°C and 90% RH for 12-16 hours to rehydrate and revive the lyophilized *Pediococcus*. Then the smokehouse temperature is increased to 41-43°C and heavy smoke is introduced. The fermentation, which takes 30-40 hours, is followed by mellowing. A milder product is obtained if the aging step is omitted. Unlike the traditional process, nitrite rather than the nitrate is the curing agent. The introduction of a commercial frozen concentrated culture of *P. acidilactici,* eliminated the revitalizing step necessary when the lyophilized culture is used. The use of a frozen concentrate of *Lactobacillus plantarum* and *P. acidilactici* allowed sausage manufacturers to use fermentation temperatures ranging from 27-43°C. Thus, the use of frozen starter cultures and air conditioned smokehouses could give Lebanon bologna producers more control over their fermentation and, consequently, a more consistent product. However, they have been very reluctant to accept these innovations. A further advantage of starter cultures is the use of nitrite as the curing agent. The dependence on bacterial reduction of nitrate to nitrite is eliminated and a more reliable curing action is obtained.

Technological and Microbiological Research at ERRC

Process developed. (Figure 1; references 1 and 2)

Coarse ground cow chuck was mixed with 3% NaCl, placed in plastic bags, and aged at 5°C for at least 10 days. During aging of the meat, micrococci and lactic acid bacteria develop. To produce a good fermented sausage with low pH, the numbers of lactic acid bacteria at the end of the aging step should be 10^4-10^5/g. For fermentation of the meat after being aged, sucrose, glucose, spices, and the legal limit of nitrate were mixed into the salted meat, and the mixture was finely ground and stuffed into fibrous casings. The sausages were smoked and fermented in a smokehouse at 35°C and 90% RH for four days. During the early part of the fermentation, both the lactic microflora and micrococci increased rapidly to $> 10^8$/g, but by end of fermentation, both populations had decreased. The role of the lactic acid bacteria was to ferment glucose (and sucrose) to lactic acid; and that of the micrococci to reduce nitrate to nitrite with concomitant production of cured meat col-

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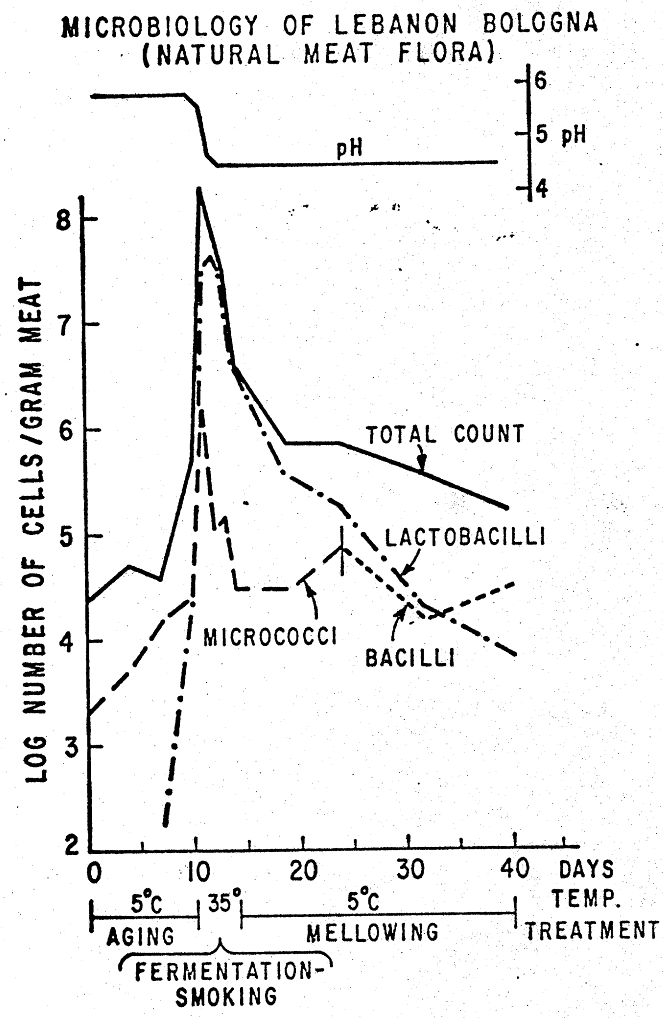

FIGURE 1

Changes in pH and bacterial populations during aging, fermentation/smoking, and extensive mellowing in Lebanon bologna manufacture (ERRC traditional process).

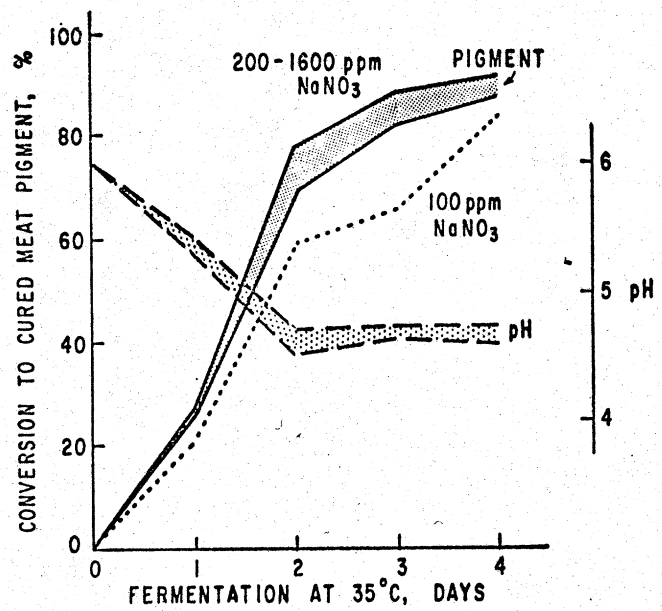

FIGURE 2

Formation of cured meat pigment and changes in pH in Lebanon bologna prepared with varying levels of $NaNO_3$ (traditional process). (From Reference 3. Reproduced with permission of the Editor of Journal of Food Science.)

TABLE 1

EFFECT OF VARYING CONCENTRATIONS OF $NaNO_2$ ON THE PROPERTIES OF LEBANON BOLOGNA FERMENTED 4 DAYS AT 35°C WITH NATURAL FLORA

(From Reference 3. Reproduced with permission of the Editor of Journal of Food Science.)

Initial pH 5.93; 0.23% lactic acid

Sausage	pH	Lactic acid (%)	$NaNO_2$ (ppm)	Pigment, % conversion
No cure	4.74	4.48	<2	—
50 ppm $NaNO_2$	4.77	0.47	5	82
100 ppm $NaNO_2$	4.77	0.48	5	85
200 ppm $NaNO_2$	4.80	0.44	8	82
400 ppm $NaNO_2$	4.94	0.40	18	76
1600 ppm $NaNO_2$	5.24	0.31	310	28
1600 ppm $NaNO_3$	4.70	0.51	7	84

or. After fermentation, the bolognas were mellowed at 5°C for at least 3 days. During this period, the micrococci disappeared completely and the lactobacilli decreased to 10^4-10^5/g. A typical Lebanon bologna prepared by the ERRC process had a pH of 4.5, 1.3% lactic acid, 11% fat, 20% protein, and 61% moisture.

When the commercial mixed starter culture was used to prepare Lebanon bologna, the procedure was similar to the traditional method except that the aging step was omitted and either nitrate or nitrite was the curing agent.

Nitrate and nitrite. (Figure 2 and Table 1; references 3 and 4)

In response to recent concern about dietary intake of nitrate and nitrite, research has been directed toward lowering the level of these curing salts in Lebanon bologna. Commercial producers formulate Lebanon bologna to contain 1600-1700 ppm sodium nitrate. We prepared Lebanon bologna of satisfactory color, pH, and texture by the traditional and the starter culture method using sodium nitrate ranging from 100-1600 ppm or sodium nitrite ranging from 50-400 ppm. Our research has indicated that substantially lower levels of curing salts can be used in the preparation of Lebanon bologna, thus lessening their dietary intake and the potential for nitrosamine formation either *in vivo* or in product. The potential for nitrosamine formation in Lebanon bologna is suggested because of the low pH of the sausage, use of high nitrate levels which could lead to potentially high nitrite levels, and a long fermentation in the presence of bacteria that produce acid, reduce nitrate, and may even be directly involved in nitrosamine formation. However, we could not detect volatile nitrosamines during the manufacture of Lebanon bologna or in the final product.

Spices and salt. (References 1, 2, and 5)

Since spices are usually considered to have antimicrobial activity, the observation that the Lebanon bologna spice mixture was stimulatory to fermentation in both the traditional and starter culture methods was unexpected. When spices were present during the fermentation, there was an increase in the acid production and a greater lowering of pH.

Lebanon bolognas prepared from meat aged with 0-2% salt were unsatisfactory. The fermentation proceeded rapidly but the sausages were defective in texture, taste, and aroma because of excessive growth of pseudomonads during the aging period. Bolognas prepared from meat aged with 4% NaCl did not ferment because the lactic microflora failed to develop during the aging period. The best bolognas were produced with meat aged with 3% salt. The growth of pseudomonads was inhibited but that of the lactic acid bacteria was not.

The fermentative ability of the commercial mixed starter culture was progressively inhibited by increasing the salt concentration from 0-7%. The addition of the Lebanon bologna spice mixture reversed that inhibition. The best Lebanon bologna prepared with that starter culture was obtained with 2-3% salt.

Survival of salmonellae. (Figures 3 and 4; reference 6)

Viable cell counts of *Salmonella dublin* added to salted meat at the beginning of the aging period nei-

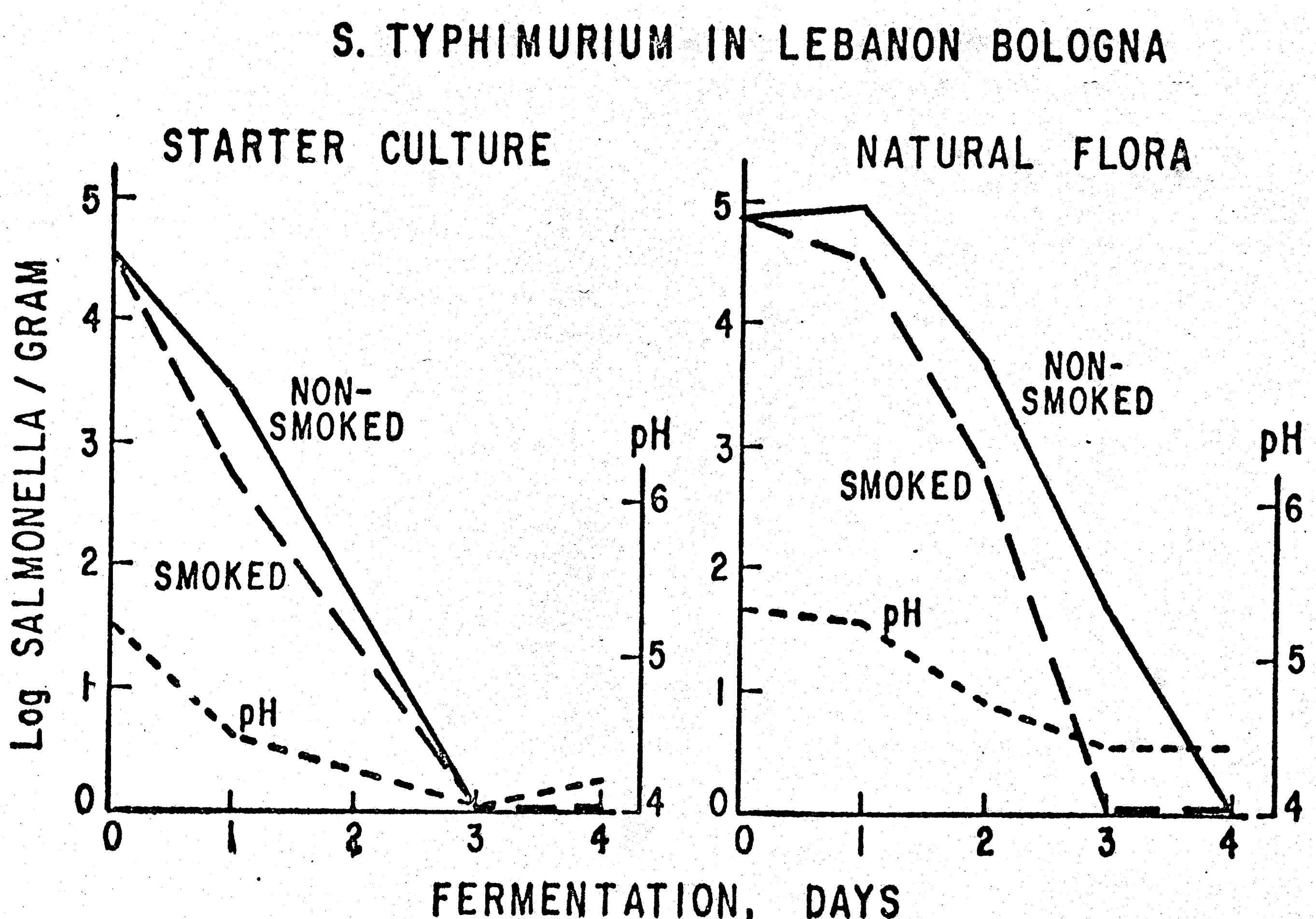

FIGURE 3

Destruction of "Salmonella typhimurium" during fermentation of Lebanon bologna.

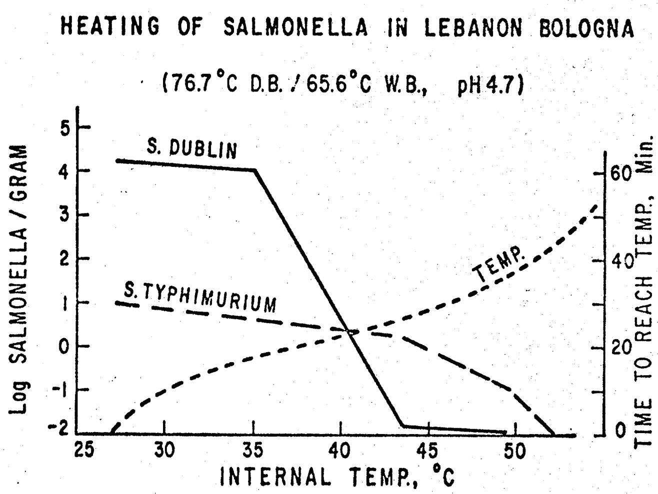

FIGURE 4

Effect of cooking of Lebanon bologna on the destruction of salmonellae.

ther increased nor decreased in 10 days at 5°C. Cell counts of S. *dublin* (initially present at 10^4/g) decreased substantially during a four day fermentation at 35°C and decreased further during the mellowing at 5°C. Numbers of S. *typhimurium* (initially present at 10^4/g) decreased to an undetectable level during fermentation. Although cooking is not a normal step in processing, heating Lebanon bologna to an internal temperature of 52°C or higher eliminated all salmonellae. *Salmonella* species were destroyed more rapidly in Lebanon bologna prepared with the frozen mixed starter culture concentrate than in those prepared traditionally. However, in the absence of fermentation, there was little reduction in salmonellae. Smoking also appeared to contribute to salmonellae destruction.

In conclusion, our research has shown that nitrite or substantially lower levels of nitrate can be used to produce Lebanon bologna of satisfactory color, pH and texture. Further, though the potential exists for nitrosamine formation during Lebanon bologna processing, we detected none in either pilot plant or commercial product. We found that spices used to prepare Lebanon bologna would stimulate acid production by the natural flora or the starter culture. Lastly, we found that salmonellae which were added to the meat during processing would be killed by the acid produced, especially when starter culture was employed to ferment the bolognas.

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DISCUSSION (Processed Meats Session)

VERN CAHILL, Ohio State University: This is for Sam. Did you employ any techniques to assure the presence of fermentative organisms in the natural flora process?

SAM PALUMBO: The presence of salt in the cold at 5°C essentially enriches for lactic acid bacteria and for the micrococci and we usually find that in our final product after 10 days under those conditions we get about 10^4 factor bacilli per gram which is enough to give us a fermentation. It is—I won't say difficult—you have to sort of believe in the process after a while. One of the real problems is counting the number of lactic acid bacteria. What we used to do, when we first got into the area, was, after seven days, to try to do a plate count, figuring that it took three days or four days to give the plate count and we would have some idea about how many we had. Often this wouldn't work because, first of all we didn't have enough to count on the plate, and, second of all it took more than three days to detect them. It does work and based on our work, I would say that it is not really a build-up of organisms in the plant. Almost anywhere are probably enough lactic acid organisms on the meat that will develop if held under the right conditions. We were led to believe, in our original studies, that you had to have an old wooden barrel that Great Grampa used. We just took a plastic bag for most of our work and put the meat with 3 percent salt in and it works beautifully.

BOB KAUFFMAN, Wisconsin: I'd like to direct a question to Dr. Acton. Could you tell us exactly what's going on physically or chemically. I think you mentioned that the product shrank when you added up to 4 percent salt as compared to addition of no salt. What is specifically happening to create this shrinkage in size?

JIM ACTON: That's Sam's study, so I'll let him answer that.

SAM PALUMBO: I don't really know what that was. It was an observation. Essentially, if you looked at the pepperoni after they dried, the ones with no salt were just—I don't want to describe them as spongy—but they looked like they had air spaces in them. They just did not compact after drying.

BOB KAUFFMAN, Wisconsin: All right, the second question to you then, Sam, is what's going through your mind concerning the effect of spices in lowering your pH, especially when you compare it to the sterile category versus the non-sterile? You get this one whole pH unit change. What is specifically happening here?

SAM PALUMBO: It essentially is a stimulation of acid produced. The exact mechanism we haven't investigated.

BOB KAUFFMAN, Wisconsin: Yea, that's what I'm talking about—what is the mechanism involved? I can see what's happening, but why do you think this is happening?

SAM PALUMBO: My idea at this point is that there is some co-factor in the spices . . .

At this point Dr. *Zyke* of our group and Mr. Kissinger have looked in detail, I believe, at the white pepper, red pepper, and allspice, and the fact that all three of these do simulate acid production leads to some interesting possibilities of what the co-factor might be. Spices are quite different in structure and the fact that all of them do give stimulation does leave the field wide open as to what it could be.

BRUCE EASON, Fairmont Foods: I had a similar question to what Kauffman had. I'd also like to ask have you done any work on the staph problem that may exist in these type products?

SAM PALUMBO: We're doing that right now. I left my colleague back at the shop doing staph counts.

JIM PRICE, Michigan State: I had three questions; two of them have already been asked. But I have one for Jim Acton or Terrell either one. A couple of the speakers made the comment that in the textbook or the reading material with which we are familiar, the comment is made that the salt is added near the end of the cycle in semi-dry and dry sausage preparation to avoid extraction of soluble protein for bind reasons. One of Jim Acton's comments was that the grinding procedure didn't seem to make any difference. I would like to ask the question is there really any effect of the selection of the time at which the salt is added or the degree of mixing or massaging on the chemistry and fixture of the dry sausage? Does it make any difference? It's in the book, but does it make any difference?

JIM ACTON: I'm not sure, Jim. I have some reservations about it. I believe that it's possibly true but I'm not aware of any study where it has been done. I definitely feel that sometimes, although particle size may not be involved, the actual time of mixing may be involved with the rate at which you would lose moisture during the drying period.

JIM PRICE, Michigan State: Wasn't that statement based pretty much on the fact that if you did add salt early in the process and you did continue to chop, blend, mix through that massaging mechanical thing, then you might get into too much of the myofibrillar and sarcoplasmic binding aspect, which would then prevent uniform drying? I think that was the process behind it and it made pretty good sense as far as, you know, being able to on a manufacturing scale to either prove or disprove it. I think it might be kind of difficult.

JIM ACTON: You want enough tackiness so that the product will hold together while you're fermenting it. If you've ever tried to ferment a material out to a pH of 5.0 and then stuff it, as in some of these aging studies, you have a mess on your hands. It won't bind back together when you start heating it. Sometimes you have in those type of studies in textbooks or *Deibel's* early work when they were working on the starter cultures, stuffing would sometimes be done after the green room. If it falls apart, it fermented too fast, and you have a problem getting it stuffed. Think about it in terms of—let me see, if I can reconstruct the picture—you add salt toward the end of the mixing so that it doesn't get mixed in very much, you get just a slight amount of tackiness. Also, the aspect there is the fact that the protein, of course, in the presence of salt would bind water much tighter (maybe I can use that term) as compared to what you might find on the interior of the product. OK, think about it in terms of comminuted products. One of the first ingredients that goes in is the salt and if you're going to add any fillers or (excuse me, that word) if you're going to add any milk powder or cereals or something like this, you add them after that water has gone in so that they don't get hydrated and compete with water with your myofibrillar proteins. So it's just the reverse there because you want them hydrated.

R. N. TERRELL: From a practical standpoint, I can see where if you had problems in stuffing, you might want to add the salt last. (I don't know if you've ever tried to stuff out something near the freezing point before or not, but it's a pretty difficult task to do), I know we had the same thing in the Hollymatic machines and tried to get the meat patties formed and some people were going to too high a salt level and they couldn't get them to drop off the end of the machine. It was just like cookie dough sticking up there. That might be a reason for that statement, but we're just postulating really. It would be a good project for Michigan State I think, Jim.

JIM ACTON: You would think it would have something to do with moisture loss and that's the statement that's always attributed to it, but you take the study of Sam's and he showed no difference in yield whether you had 0, 1-4% of salt added. That may, in effect, destroy part of that theory. Of course that didn't have anything to do with where you added it.

BILL SCHWARTZ, Peter Eckrich: Mr. Hope, a question for you. You suggested that operational tests would be in order when you're changing an operational procedure. Could you expand on that a little bit and tell us what characteristics are generally evaluated and how that's done?

JERRY HOPE: What we've done in the past is if it was a piece of equipment that we wanted to have a new application, say a stuffer, and it had not been used on dry sausage, what we would do is get a test unit, or take a unit from an existing plant, and actually run it through its cycles in the different characteristics of the meat and see if it's practical or not. We've also made test smokehouse units or test module units and actually studied the drying cycles, changed and modified duct work, air cycles, reversing of air, and other things along this line. We actually did test models on taking some of the normal production product line and putting it in test model and compared it to the product on the existing drying facilities.

EUGENE WIERBICKI, Natick Laboratories: I have a question for Dr. Palumbo. Before I left industry, I worked with Lebanon bologna. I speak about Genoa salami . . . transmission problems.

SAM PALUMBO: Well, that was for the salmonella survival. Fresh meat is just meat that was not treated and it is just plain meat. The aged meat was meat that was held in the cold for ten days with salt to develop the microflora. Then the starter culture was fresh meat plus the starter culture. The purpose of that was to show comparison. The fresh meat was to simulate a condition in which no fermentation would occur and to show what would happen to the salmonella in that instance. Overall, in terms of all of the factors that we looked at, especially if you used the traditional process, 3 percent is the one that will suppress the pseudomonads and yet allow enough lactic acid organisms to develop to give you a good fermentation. With the starter culture, when you go beyond 3 percent, you start getting a product that is excessively salty. It is just unacceptable I think to most people.